COS 425:
Database and Information
Management Systems

Crash Recovery

Crash Recovery Overview

- Goals of crash recovery
  - Either transaction commits and is correct or aborts
  - Commit means all actions of transaction have been executed
- Error model:
  - lose contents main memory
  - disk contents intact and correct

Crash recovery requirements

- If transaction has committed then still have results (on disk)
- If transaction in process, either
  1. Transaction completely aborts

  OR
  2. Transaction can continue after restore as if no crash
- Get serializable schedule such that transactions that committed before crash still commit and in same order

=> NEED LOG

ARIES algorithm

- Assumptions
  - Strict 2PL => no cascaded aborts
  - "in place" disk updates: data overwritten on disk
    - Page read into buffer, changed in buffer, written out again
    - Write of page to disk is atomic
- Log:
  - Sequential writes on separate disk
  - Write differences only
    - Multiple updates on single log page
    - Each log record has unique Log Sequence Number
      - LSN strictly sequential

Contents of a log record

- prevLSN for transaction
  - creates linked list of LSNs for transaction going back in time
- transaction ID
- Type
  - update, commit, abort, end, CLR (compensation log record)
- Update information
  - page ID
  - length & offset
  - before data & after data

Bookkeeping: tables

- Transaction table
  - transaction ID
  - status: running, committed, aborted
  - lastLSN
    - points to most recent prevLSN
    - start of chain
- Dirty page table
  - ID of each page with changes not yet on disk
  - recLSN for each page:
    LSN of log record for earliest page change not on disk

These tables in main memory

Other bookkeeping

- pageLSN for each data page
  - is LSN of most recent log record for update to that page
  - is stored on data page
- flushedLSN
  - maximum LSN already written to disk
  - is stored in memory
- Requirement: write data page to disk only after write log entries to disk
  - pageLSN <= flushedLSN on data page write

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Checkpoint

- Properties
  - Goes on while other transactions running
    - as separate transaction
  - does not flush dirty pages to disk
  - does tell us how much to fix on crash
- Actions
  1. Write "begin checkpoint" to log
  2. Write current transaction table and dirty page table and "end" as one record to log
     - tables as of "begin checkpoint"
  3. Write log to disk
  4. Store LSN of "begin checkpoint" in safe place
     - "master record"

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Commit

Actions

1. write "commit" to log
2. write to disk all log records up to commit record
3. clean up transaction table,etc.
4. write "end(commit)" record to log

- commit is executed as soon as disk write finishes
- if crash before table clean-up, transaction will commit on recovery

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Update

Actions

1. *Pin* data page in buffer and write change
2. Write log entry (LSN=#)
3. Update transaction table (lastLSN = #)
4. Update dirty page table
5. Write pageLSN= # to page and *unpin* page

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Transactions do concurrently (mixed)

- Commit
- Abort (those not part of restart after crash)
- Checkpoint
- Update

Crash recovery manager does alone:

All actions during restore of database during restart after crash

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When write to disk

- Write log pages from buffer:
  - on checkpoint
  - on commit of transaction
  - When want to write data page but pageLSN > flushedLSN
- Write data pages from buffer:
  - At discretion of buffer manager
- Writing fewer log pages and sequentially: cheaper

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Crash recovery Phase I: Analysis

- Get log from disk
- Get most recently checkpointed transaction table and dirty page table
  - use *master record*
- Read log forward from checkpoint and update tables
  - For END log entries, remove transaction from transaction table
  - For other log entries, add or update transaction table entry

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Crash recovery Phase II: Redo

- REDO all actions in log starting at earliest point when a change not on disk
  - Want earliest recLSN of all recLSNs in dirty pg table
  - Includes redo of UNDOs and ABORTs
    - See Phase III
- When redo action
  - Write new pageLSN
  - Do NOT write new Log entry

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At end phase II Redo

- DB now in state was as recorded by *log on disk* at crash
- To finish phase II
  - write END log records for transactions in transaction table that were committed
  - Remove committed transactions from transaction table

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Crash recovery Phase III: Undo

- UNDO actions of all transactions not committed by the end of phase II
- Work backwards through log
  - Follow pointer chain from each still-active transaction

    lastLSN →prevLSN →prevLSN → … → prevLSN
  - To process, interleave chains in LSN order from all active transactions
    - Event queue

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Phase III UNDO Actions

- For UPDATE
  1. Write CLR record to log *NEW*
     - Records change done to undo UPDATE
     - Records undoNextLSN storing prevLSN of this UPDATE
       - Records next record to undo
     - Think of as ABORT log record like UPDATE log record
  2. Undo change in UPDATE
  3. If prevLSN for UPDATE == NULL, write END record for transaction

     Else queue prevLSN for processing

UNDO makes new DB changes =>

Need step 1 to deal with another crash as undoing

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Phase III UNDO Actions

- For CLR

  If undoNextLSN == NULL, write END record for transaction
  - Undo/abort of transaction done

  Else queue undoNextLSN for processing
  - Re-establishes prevLSN chain for undoing/ aborting transaction

- If are undoing a CLR, were in the process of undoing/ aborting a transaction when crashed
- The redo of the CLR in phase II did the actual undoing
- Don't undo the UNDO represented by CLR record!

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Effects of recovery

- REDO does “clean-up”
  - ends committed transactions
  - Writes ENDs to log
- UNDO does *new work* to undo/abort
  - Changes data pages, which may be on disk
  - Writes log entries for its actions

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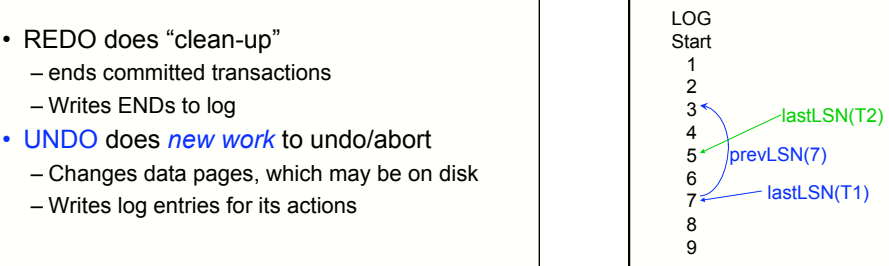
Short Example UNDO phase



- T1 and T2 to undo
- Assume neither an ABORT

Queued to undo:
LSN 7
LSN 5

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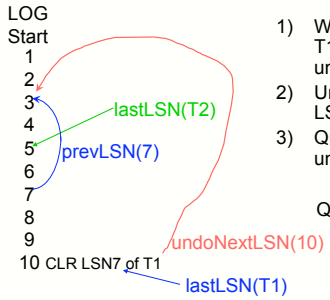
Short Example UNDO phase



1) Write “CLR LSN7 of T1” to log with undoNextLSN = 3
2) Undo action of T1 in LSN 7
3) Queue prevLSN(7) to undo

Queued to undo:
LSN 5
LSN 3

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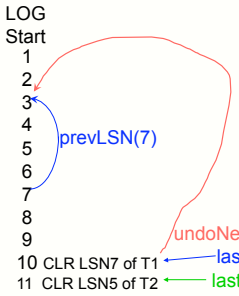
Short Example UNDO phase



1) Write “CLR LSN5 of T2” to log with undoNextLSN = null
2) Undo action of T2 in LSN 5

CRASH

Queued to undo:
LSN 3

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Short Example UNDO phase

CRASH

Assume log through entry 11 was written to disk

Look at new UNDO phase

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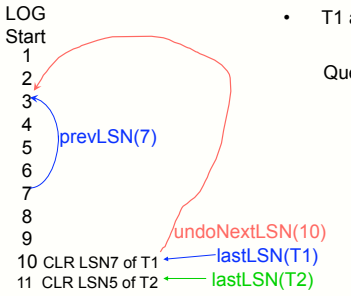
Short Example UNDO phase



- T1 and T2 to undo

Queued to undo:
LSN 11
LSN 10

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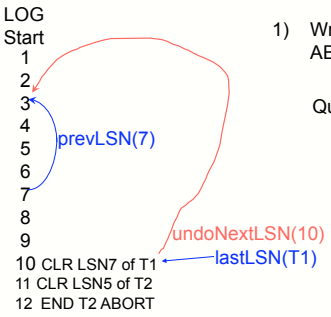
Short Example UNDO phase



1) Write "END T2 ABORT" to log

Queued to undo:
LSN 10

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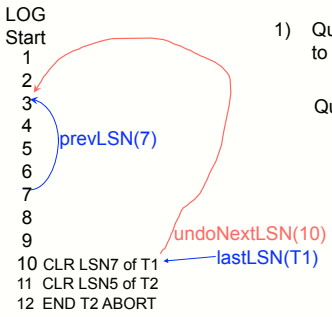
Short Example UNDO phase



1) Queue undoNext(10) to undo

Queued to undo:
LSN 3

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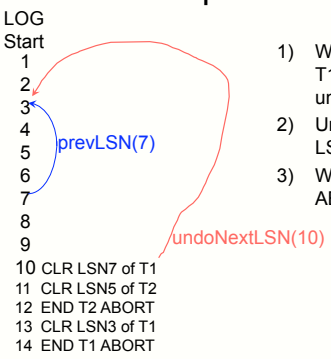
Short Example UNDO phase



1) Write "CLR LSN3 of T1" to log with undoNextLSN = null
2) Undo action of T1 in LSN 3
3) Write "END T1 ABORT" to log

Queue Empty

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Abort as part of a transaction

- Write ABORT log record
  - Analogous to COMMIT but more to do before END
- Execute UNDO phase for
  lastLSN →prevLSN →prevLSN → … → prevLSN
  of the aborting transaction
- When UNDO phase writes END to log, is end of ABORT of transaction
  - Must remove from transaction table

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